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(54) Abstract Title
Micromotor

(57) An array 1 of micromotors 2 is formed from a sheet 3 of piezoelectric material. The sheet 3 is cut to define the micromotors as a plurality of elongate legs 5 which are connected together by a bridging portion 6 at one end of each leg 5 and which extend to the remainder of the sheet 3. The bridging portion 6 mounts a contact pad 7. The legs 5 are angled away from the remainder of the sheet 3. Each of the legs 5 has a pair of electrodes 8 extending along the legs 5 on the opposed major surfaces of the sheet 3 for applying an electric field across the sheet, the material being poled across the sheet 3 for activation in an expansion-contraction mode. In use, a periodic control voltage is applied across the pair of electrodes 8 for each leg 5 with a predetermined phase relationship between the control voltages for each leg 5. The resultant expansion and contraction of the legs 5 moves the pad around an orbital path allowing the pad 7 to drive movement of an object. The micromotors 2 are easy to manufacture by cutting and pressing a sheet 3 of piezoelectric material.

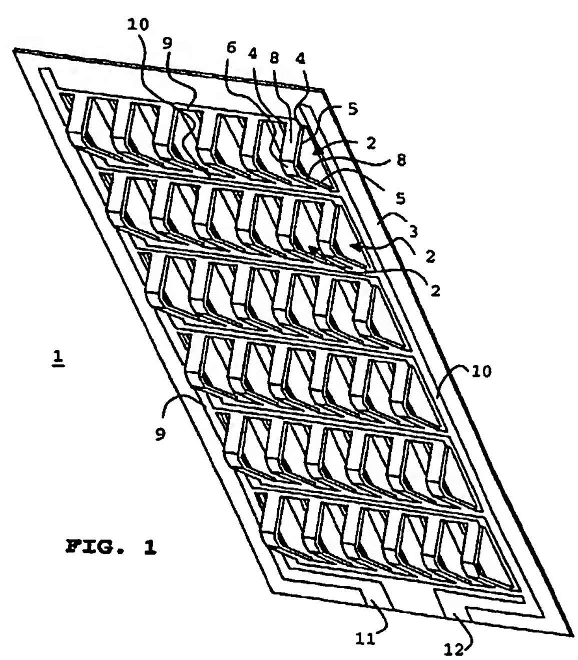

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

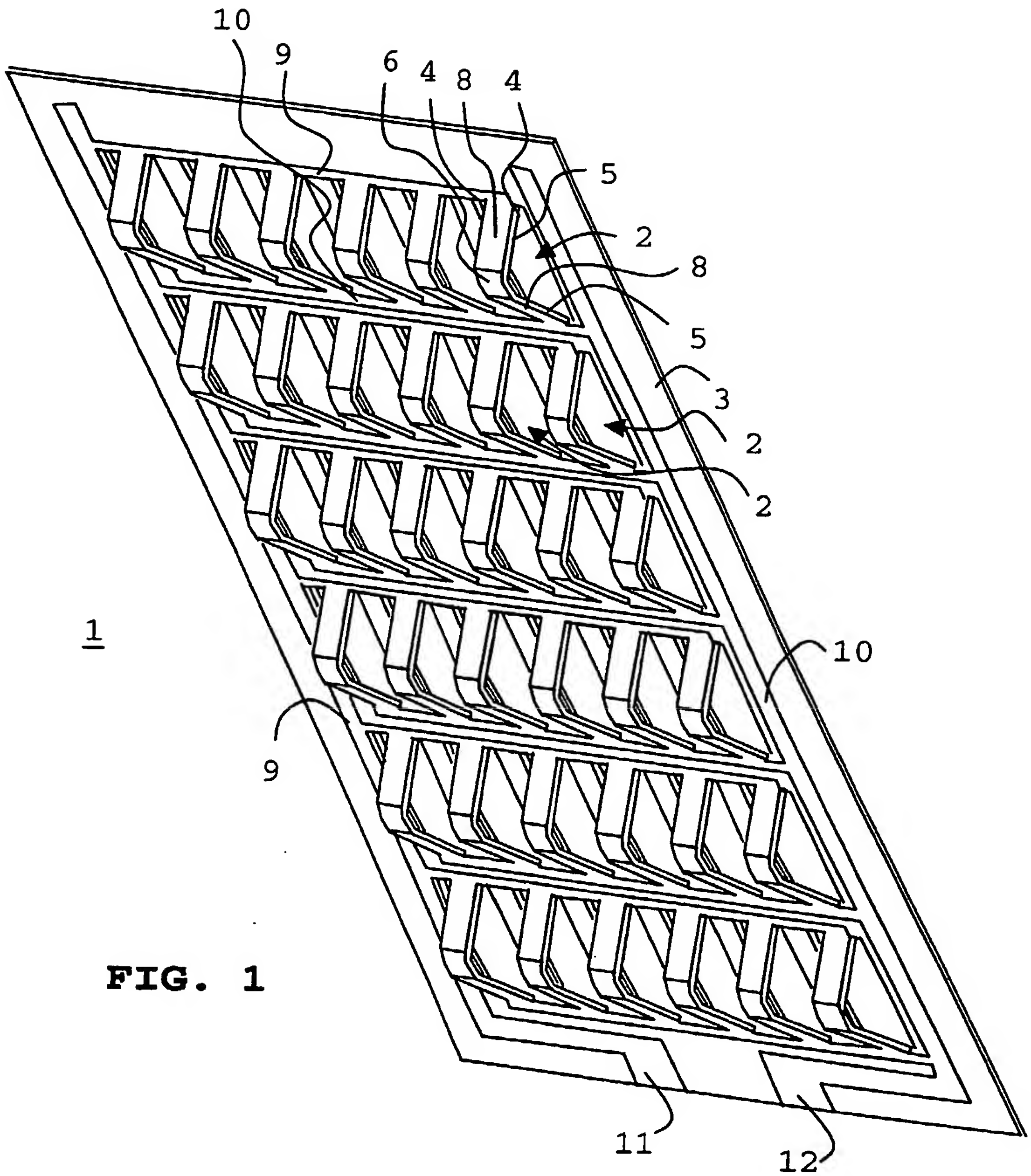
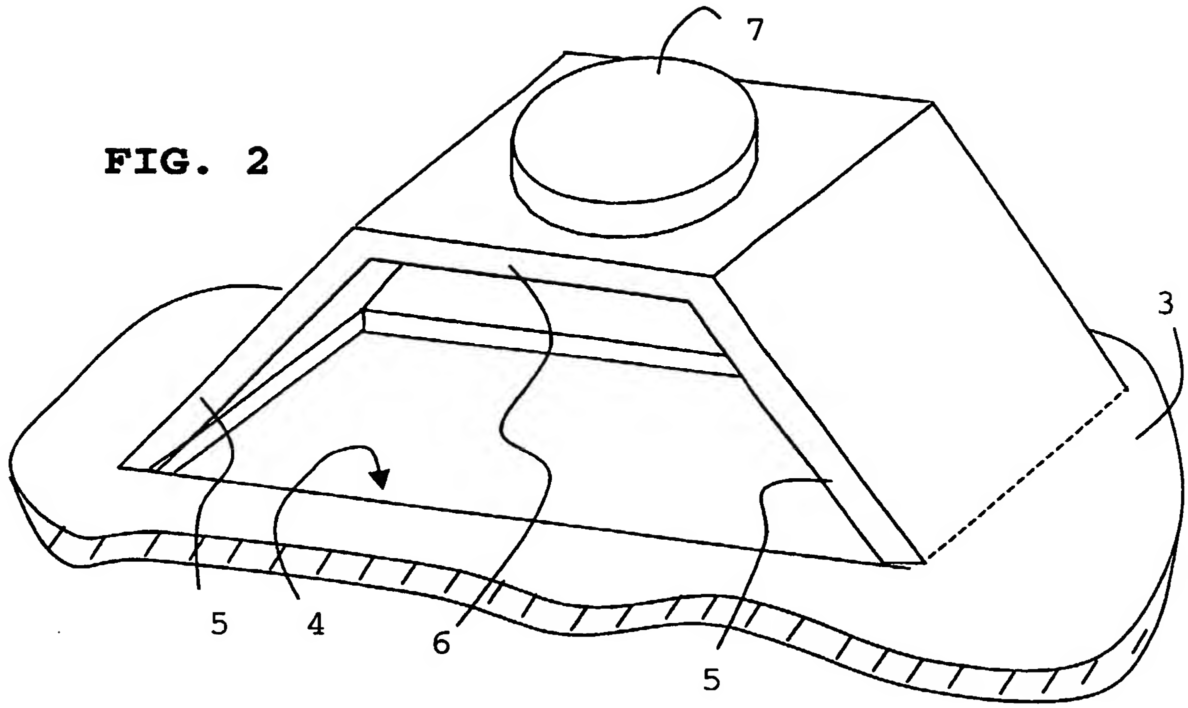


FIG. 1

FIG. 2



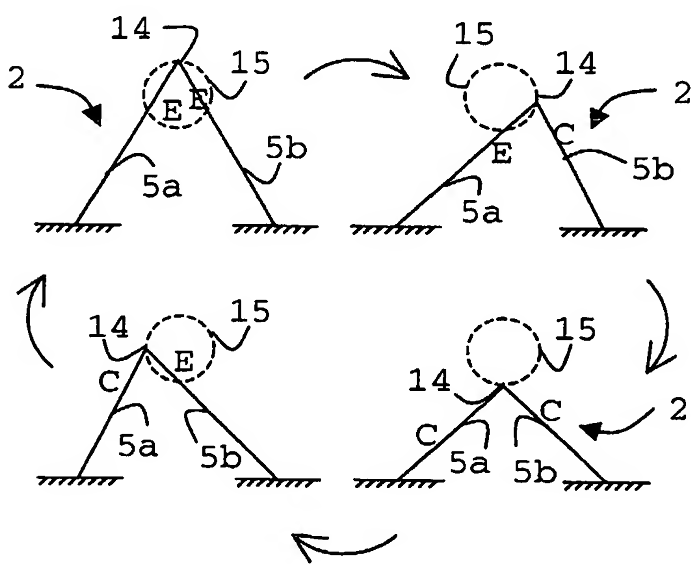


FIG. 3

FIG. 4A

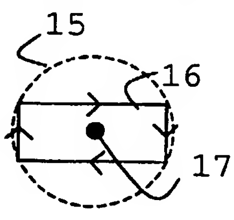


FIG. 4B

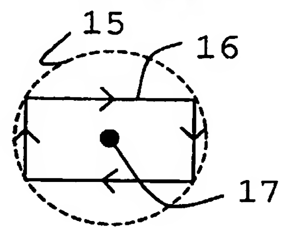
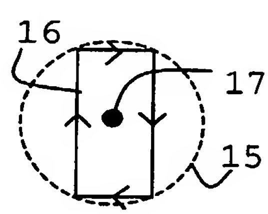


FIG. 4C



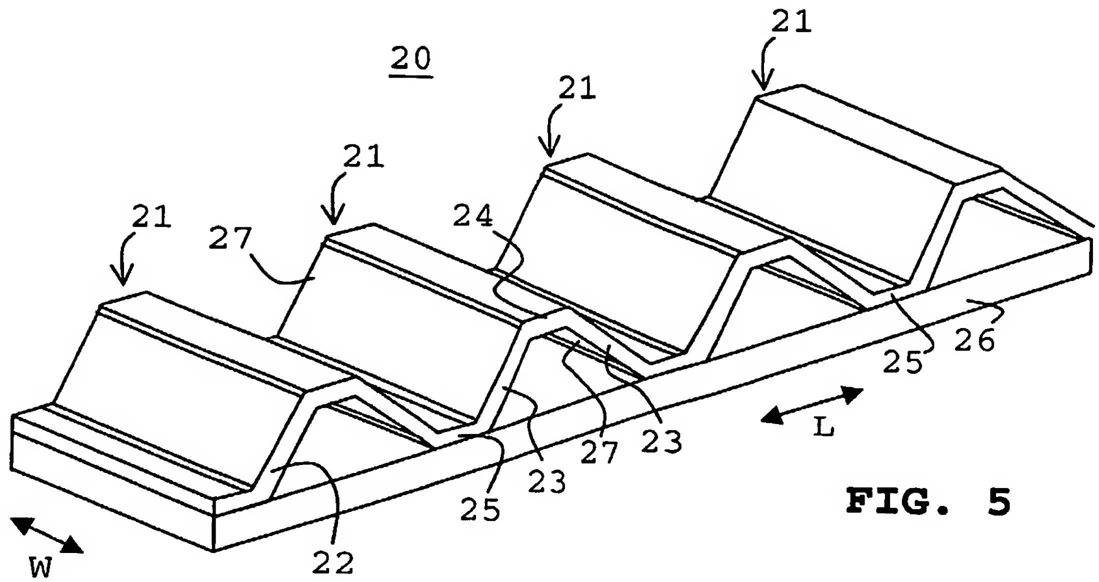


FIG. 5

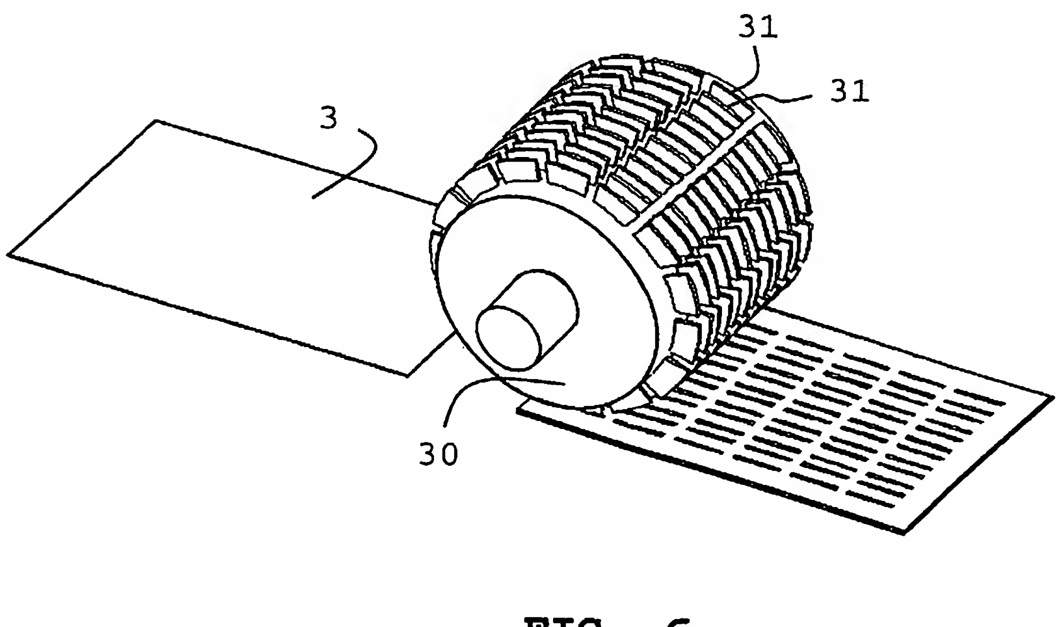


FIG. 6

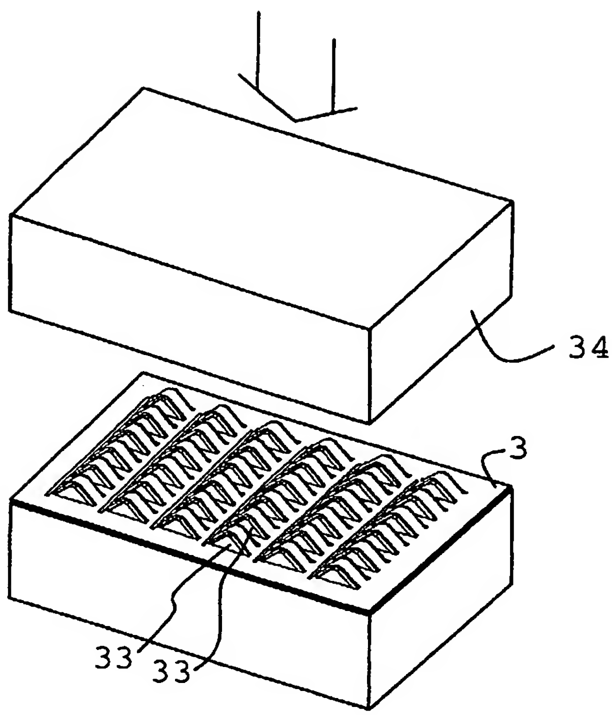


FIG. 7

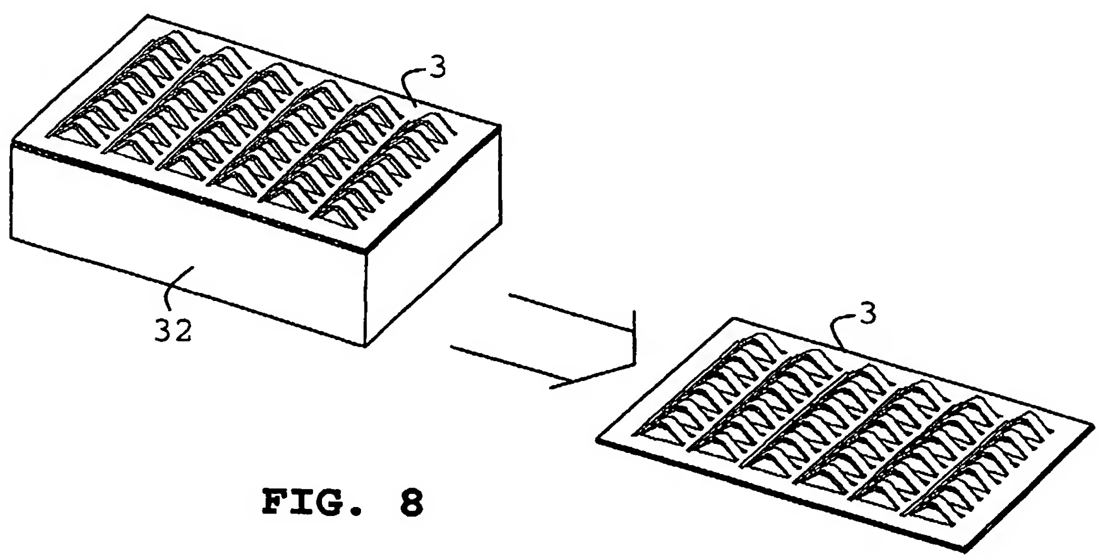


FIG. 8

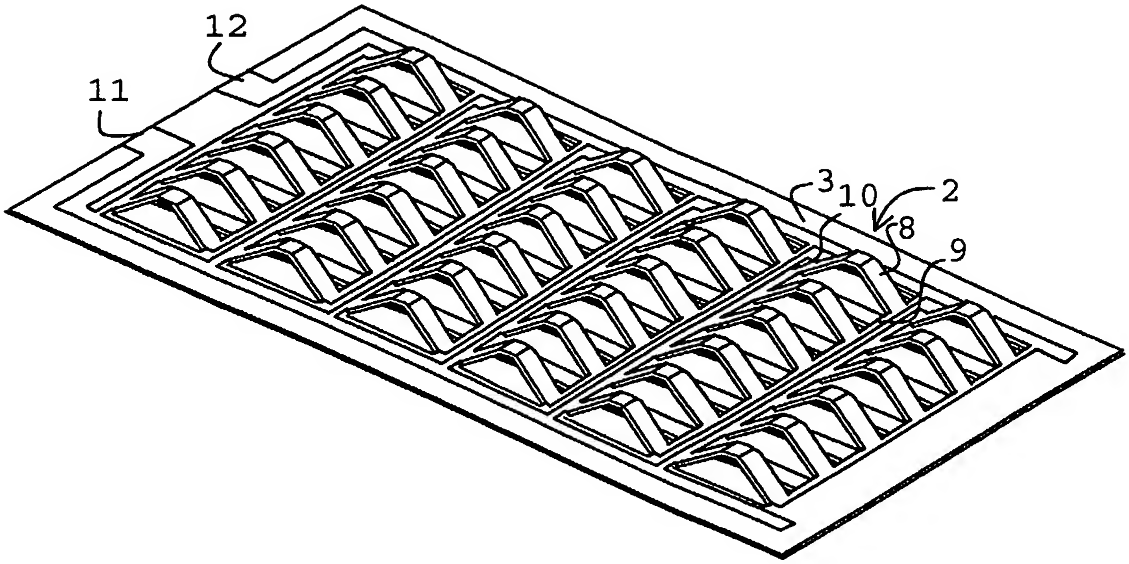


FIG. 9

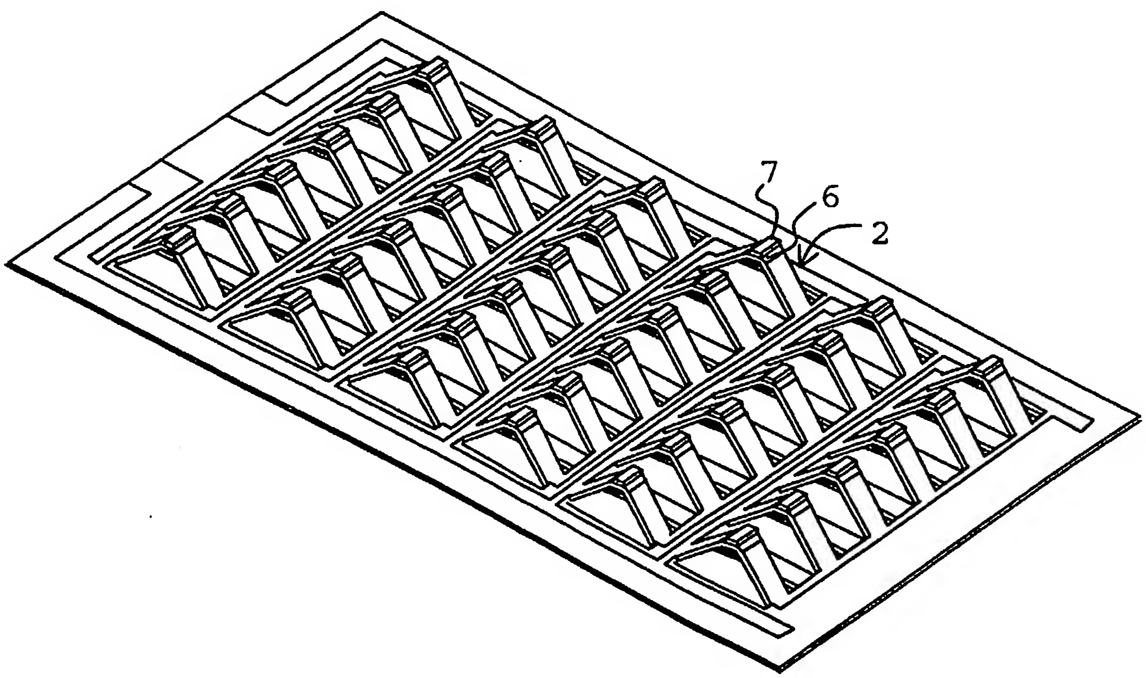


FIG. 10

Micromotor

The present invention relates to micromotors employing piezoelectric material to drive continuous motion of an object by a vibratory motion of the piezoelectric material.

Piezoelectric material deforms when an electric field is applied across the material to activate it. Many motors employing piezoelectric material with electrodes for applying the electric field for activation are known. However, the piezoelectric effect is small. Displacements derived from a simple block of piezoelectric material are small, typically less than a micron. Hence, motors using piezoelectric material are typically termed micromotors.

To achieve a higher degree of movement, it is known to provide a micromotor with a structure which on activation vibrates in a reciprocal or orbital path. Thus the vibration of the micromotor can be used to drive continuous movement of an object. An example of such a micromotor is disclosed in US-5,453,653 in which the micromotor comprises a piezoelectric plate having electrodes arranged in the four quadrants of the plate so that appropriate activation voltages applied to the electrodes drive vibratory motion of one end of the plate. To generate higher forces, US-5,453,653 also discloses an array of micromotors coupled together.

One problem with known micromotors for driving continuous motion of an object, such as that disclosed in US-5,453,653, is that they have a structure which is difficult to manufacture. In particular, it is difficult to manufacture an array of such micromotors. Often, it is necessary to manufacture each micromotor individually and subsequently to connect the micromotors together in an array, which is inconvenient and difficult to achieve the necessary tolerances in coupling the micromotors together. It would be desirable to identify other structures for a micromotor which simplify the manufacturing process, in particular for an array of the micromotors.

According to the present invention, there is provided a micromotor, comprising a plurality of members of piezoelectric material, wherein the members are connected together at one end of each member from which the members extend to

a support at an angle from each other so that the micromotor protrudes from the support, each of the members having a pair of electrodes extending along the members on opposite sides of the members for applying an electric field across the material of the members, the material being poled parallel to the direction of the electric field.

In use, the micromotor is activated by applying control voltages across the pair of electrodes for each member. As the material is poled parallel to the direction of the electric field, the members are activated in an expansion-contraction mode and the members change in length in response to the applied control voltage. The control voltages for each member are periodic and applied with a predetermined phase relationship. Due to the members being constrained by being connected to the support and to each other, the resultant change in length of the members causes the ends of the members which are connected together to move around an orbital path. Such vibratory movement of the connected ends of the members may be used to drive continuous movement of an object.

A significant advantage of the micromotor in accordance with the present invention is that it may be operated below resonance of the structure of the micromotor. This has many advantages, especially in providing for accurate control of the micromotor motion.

The members are preferably elongate.

Advantageously, the members are connected together through a bridging portion. The bridging portion may be used to contact the object to be used, either directly, or indirectly by a pad affixed to the bridging portion.

Micromotors in accordance with the present invention are usually provided together in an array to provide together a significant driving force.

Micromotors in accordance with the present invention are easy to manufacture by shaping a sheet of piezoelectric material it is particularly simple to manufacture a micromotor array from a single sheet. Thus in accordance with a second aspect of the present invention there is provided a micromotor array comprising a sheet of piezoelectric material, portions of which are shaped to form

respective micromotors each comprising a plurality of members connected together at one end and each extending to the remainder of the sheet at an angle to the remainder of the sheet and at an angle to each other, each of the members having a pair of electrodes extending along the members on opposite sides of the members for applying an electric field across the material of the members, the material being poled parallel to the direction of the electric field.

In the preferred method of manufacture, the micromotor is formed from a sheet of piezoelectric ceramic in a green state. The sheet may be cut to define the micromotor with the members connected together and connected to the remainder of the sheet which therefore acts as a support for the micromotor. Alternatively the micromotor may extend across the entire width of the sheet. The sheet is pressed to angle the members away from the remainder of the sheet to provide the members with the desired angled orientation. The members are easily angled, because piezoelectric ceramic is deformable in the green state. Subsequently the sheet is sintered to set the piezoelectric ceramic with the members in their angled orientation.

Forming the micromotor from a sheet of piezoelectric material makes it particularly easy to manufacture an array of micromotors. This is because all the micromotors may be formed simultaneously. For example a sheet of piezoelectric material may be cut by passing the sheet over a roller having blades defining a cutting pattern for the micromotors. Similarly, pressing of all the micromotors in the array may be performed simultaneously in a single press.

To allow better understanding, embodiments of the present invention will now be described by way on non-limitative example, with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of a micromotor array;

Fig. 2 is a perspective view of a micromotor of the array of Fig. 1 mounted with a contact pad;

Fig. 3 is a schematic diagram of a micromotor of the array of Fig. 1 at four points in its motion;

Figs. 4A to 4C illustrate rectangular orbital paths for the movement of the

micromotor;

Fig. 5 is a perspective view of a further micromotor array;

Fig. 6 is a perspective view of a cutting stage in a manufacturing process;

Fig. 7 is a perspective view of a pressing stage in the manufacturing process;

Fig. 8 is a perspective view of a sintering stage in the manufacturing process;

Fig. 9 is a perspective view of a sintering stage in the manufacturing process; and

Fig. 10 is a perspective view of a stage for applying electrodes in the manufacturing process.

Fig. 1 illustrates a micromotor array 1 comprising a regular, rectangular array of micromotors 2 formed in a single sheet 3 of piezoelectric material.

Each micromotor 2 is defined between a pair of straight parallel cuts 4 in the sheet 3. The piezoelectric material between the cuts 4 defines members in the form of two elongate legs 5 connected together at one end by a bridging portion 6 disposed between the legs 5. At the opposite end from the bridging portion 6, the legs 5 are connected to the remainder of the sheet 3 which acts as a support for the legs 5. The legs 5 extend in the same direction as viewed perpendicularly to the sheet 3. The legs 5 extend at an angle from the remainder of the sheet 3. As a result, the legs 5 similarly extend at an angle from each other, and the micromotor 2 protrudes from the remainder of the sheet 3 with the ends of the legs 5 connected by the bridging portion 6 positioned away from the remainder of the sheet 3. All the micromotors 2 in the array 1 are aligned in the same direction as viewed perpendicularly of the sheet.

The bridging portion 6 extends parallel to the remainder of the sheet 3 beyond the end of the legs 5 and therefore at an angle to the legs 5. Accordingly, all the bridging portions 6 of the micromotors 2 within the array 1 are co-planar with each other.

In use, the bridging portion 6 may contact an object to be moved (not shown) or alternatively, as illustrated in Fig. 2, may mount a contact pad 7 for contacting the object to be moved. Such a contact pad 7 may be made of a material providing suitable wearing and/or frictional properties for engaging and driving movement of the object. One suitable material for the contact pad 7 is a hard ceramic, such as

alumina.

However, the provision of a bridging portion 6 is not essential and instead the legs 5 may be connected directly to each other, thereby providing a sharp edge therebetween which in use contacts the object to be moved. However the provision of a bridging portion 6 between the legs 5 is advantageous to provide a large surface to engage the object or to firmly mount the contact pad 7 for engaging the object.

Each leg 5 has a pair of electrodes 8 formed on the opposed major surfaces of the sheet 3 of piezoelectric material. The electrodes 8 on the upper surface of the sheet 3 are visible in Fig. 1, there being an identical pattern of electrodes 8 on the lower major surface of the sheet 3. The pair of electrodes 8 extend along the length of the leg between the remainder of the sheet 3 and the bridging portions 6, as well as extending across the entire width of the legs 5. The electrodes 8 for each leg 5 of any given micromotor 2 are electrically isolated to allow independent activation of each leg 5. The pair of electrodes 8 for each leg 5 in use receive an activation voltage and therefore apply an electric field across the portion of the sheet 3 of piezoelectric material which forms the legs 5.

The piezoelectric material of the legs 5 is poled parallel to the direction of the applied electric field. This may be achieved during manufacture by applying a poling voltage between the pair of electrodes 8 of each leg sufficient to orient the crystals of the piezoelectric material. As a result of the electric field applied during activation being parallel to the poling direction, the legs 5 are activated in an expansion-contraction mode in which they undergo a change in length.

The electrodes 8 on the corresponding legs 5 of each micromotor 2 are electrically connected together by conductive strips 9 and 10 formed on the opposed major surfaces of the sheet 3. The conductive strips 9 and 10 on the upper major surface of the sheet 3 are visible in Fig. 1, with an identical pattern of conductive strips 9 and 10 being formed on the lower major surface of the sheet 3. The conductive strips 9 and 10 extend to respective terminals 11 and 12 to provide a common connection to all the electrodes 8 of the corresponding legs 5 of each micromotor 2.

The terminals 11 and 12 are electrically connected to a control circuit 13. In use, the control circuit 13 applies a periodic control voltage across the pair of electrodes 8 for each leg of each micromotor 2. There is a predetermined phase relationship between the control voltages for each leg 5. The form and phase relationship of the control voltages controls the shape of the orbital path, for any given geometry of the micromotor 2 (in particular the length and angle of the legs 5). In general, the periodic control voltages may take any form, and have any phase relationship which produce movement in an orbital path. A possibility which is simple to implement is for the periodic control voltage to be sinusoidal with a 90° phase difference between the control voltages for each leg 5 of each micromotor2. This produces an orbital path which is curved. Orbital paths with other shapes are advantageous as described below.

For each mircomotor 2, the applied control voltages cause each leg 5 to undergo a periodic change in length out of phase with each other. The legs 5 are constrained by being connected to the remainder of the sheet 3 and being connected to each other through the bridging portion 6. This causes the ends of the legs 5 which are connected together, and the bridging portion 6, to move around an orbital path. Fig. 3 is a schematic view illustrating the motion by showing a single micromotor 2 at four equi-spaced points in the cycle of the periodic control voltage. In particular, in Fig. 3 the first and second legs 5a and 5b of the micromotor 1 are illustrated by lines connected to the remainder of the sheet 3 which acts as a support with the bridging portion 6 omitted for clarity. Fig. 3 illustrates the phase relationship that the first leg 5a lags the second leg 5b by 90°. The legs 5a and 5b are labelled by the letter E when they are extended and by the letter C when they are contracted. As can be seen, the resultant motion of the point 14 where the legs 5a and 5b are connected follows an orbital path 15. The exact shape of the orbital path 15 depends on the control voltages and the length of the legs 5 and the angle at which the legs 5 extend away from the sheet 3.

In use, the micromotors 2 are arranged in contact with an object to be moved and the orbital motion thus drives movement of that object. In particular, the object is

engaged and moved sideways while the micromotor 2 moves around the portion of the orbital path 15 farthest from the sheet 3 and the object is released while the micromotor 2 moves around the portion of the orbital path 15 closest to the sheet 5.

Fig. 3 illustrates the case that the orbital path is circular or elliptical which may be achieved by using sinusoidal periodic control voltages. However, the orbital path need not be curved. Particular advantage is achieved by using an orbital path wherein the portion farthest from the sheet 3, where portion the micromotor 2 is in contact with the object to be moved, is straight. This provides the advantage that whilst the micromotor 2 is in contact with the moving body, there is no slippage and there is a constant contact force. A particular example of this is for the orbital path to be a parallelogram, preferably a rectangle or square, one side of which is oriented along the direction of movement of the object to be moved.

For example, Figs. 4A to, 4C illustrate three different orbital paths 16 which are rectangular. Each of the rectangular paths 16 is within the circular or elliptical path 15 produced by sinusoidal control voltages as illustrated in Fig.3. It will be noted that the straight portions farthest from the sheet 3 where the micromotor 2 is in contact with an object to be moved is at a different distance from the centre 17 of the orbital path 16 for each of the different rectangular orbital paths in Figs. 4A to 4C. This allows the contact force and displacement to be dynamically adjusted.

In general, it is similarly possible to adjust the contact force and displacement for orbital paths which have shapes other than rectangular by varying the degree of movement towards and away from the sheet 3. This allows dynamic control of the frictional force between the micromotor 2 and the object to be moved and also allows control of the displacement for each passage around the orbital path. Such dynamic control of the gearing and frictional force is a significant advantage.

Another particular advantage of the micromotor 2 is that it may produce orbital motion at any frequency below resonance, in contrast to many existing micromotors which rely on resonant modes to operate. This has many advantages, especially in providing accurate control of the motion of the micromotor 2. Furthermore, it is possible to control the phase relationship between the movement of

the different micromotors, so that the average displacement of all the micromotors 2 in the array 1 in the direction perpendicularly away from the sheet 3 is constant over time. For example, half of the micromotors 2 may be driven in antiphase from the other half of the micromotors 2. This has the advantage that the normal force on the object remains constant over time because different micromotors 2 in the array 1 engage the object at different times in the cycling movement of the micromotors 2. This has the advantage of reducing wear and reduces the force needed to bias the micromotor ray 1 against the object. Such control of the phase relationship between micromotors 2 in the array 1 requires that there is a different pattern of conductive strips 9 and 10 from that shown in Fig.1 to apply different control voltages to different micromotors 2 in the array 1.

In a typical micromotor 2, the legs 5 will have a length of 2mm, a width of 0.6mm and a thickness of 0.1mm. Typically, the legs 5 will extend at an angle of 45° from the sheet (ie. at an angle of 90° from each other) so that the ends of the legs 5 connected together through the bridging portion 6 are spaced 1mm away from the remainder of the sheet 3.. With this configuration and using a typical activation voltage, a micromotor 2 can generate a theoretical maximum displacement of 0.27μm with a typical lateral blocking force of 0.86N. The total lateral blocking force for the array 1 is equal to the sum of the blocking forces provided by each micromotor 2. Also, with such a typical structure, the lowest resonant frequency would be 70kHz. Therefore such a micromotor 2 could be operated at any frequency up to 70kHz and perhaps beyond. This would correspond to an actuation speed of 14mm/s at 70kHz. A typical driving frequency would be 60kHz or even 68 kHz as the resonance would be sharp.

The angle between the legs may vary provided it is greater than 0° and less than 180°. To achieve significant displacement the angle is preferably greater than 10° and less than 170°. Equally the angle of the legs 5 from the sheet 3 is less than 90° to provide the angle between the legs 5. By increasing the angle from the sheet 3 at which the legs 5 extend, it is possible to increase the displacement of the micromotor 2 at the expense of reducing the blocking force, and vice versa by

decreasing the angle it is possible to increase the blocking force at the expense of reducing the displacement.

The frictional force between the micromotor 2 and an object may be less than the blocking force of the piezoelectric material of the legs 2, particularly if the normal load between the object and the micromotor 2 is low. Therefore it is desirable to maximise friction between the micromotor 2 and the object. This may be achieved by modifying the contacting surfaces of the micromotor 2 and the object, for example by roughening. Friction may also be increased by increasing the normal loading, for example by biassing the micromotor array 1 against the object and by control of the orbital path as described above.

In the micromotor array 1 of Fig. 1, the sheet 3 is planar and therefore suitable for driving linear motion of an object. As an alternative, the sheet 3 of the micromotor array 1 could be curved along the direction of movement of the object, in which case it would be suitable for driving rotational movement of an object.

The micromotors 2 of the micromotor array 1 have two legs 5. Other arrangements employing more than two legs are equally possible. For example, in the micromotor array 1 of Fig. 1, the bridging portions 6 of each row of micromotors 2 could be coupled together by a bar extending along the row to form a larger micromotor having twelve legs. Alternatively, a micromotor could be arranged with legs extending outwardly in different directions as viewed perpendicularly to the sheet 3. In that case, the micromotor could drive movement in two directions selectively by controlling the legs extending in different directions.

The sheet 3 may be formed of any suitable piezoelectric material including piezoelectric ceramics such as lead zirconate titanate (PZT) or piezoelectric polymers such as polyvinylidenefluoride (PVDF).

Fig. 5 illustrates the further micromotor array 20 comprising a linear array of micromotors 21 formed from a single sheet 22 of piezoelectric material.

Each micromotor 21 extends across the entire width W of the sheet 22 with the micromotors 21 being spaced along the length L of the sheet 22. Therefore, for each micromotor 21, two portions of the sheet 22 extending across the entire width W

of the sheet 22 form members 23 connected together at one end by a bridging portion 24 also extending across the entire width W of the sheet 22. The remainder of the sheet 22 forms intermediate portions 25 between the micromotors 21. These intermediate portions 25 are coupled to a rigid support 26, for example by adhesive.

The sheet 22 is corrugated so that the members 23 extend at an angle from the intermediate portions 25 and the rigid support 26, and at an angle from each other. Thus the micromotors 21 protrude from the rigid support 26. The bridging portions 24 extend parallel to the intermediate portions 25 and the rigid support 26 and therefore at an angle to the members 23. Accordingly, the bridging portions 24 for all the micromotors 21 in the array 20 are co-planar with each other.

Each member 23 has a pair of electrodes 27 on the opposed major surfaces of the sheet 22, there being an identical pattern of electrodes 27 on both major surfaces of the sheet 22. The pair of electrodes 27 for each member 23 are electrically isolated to allow independent activation of each member 23, and in use receive an activation voltage for applying an electric field across the members 23. The piezoelectric material of the members 23 is poled parallel to the direction of the applied electric field.

Therefore, the micromotors 21 of the array 20 of Fig. 5 have a similar construction and operation to the micromotors 2 of the array 1 of Fig. 1, except that they extend across the entire width W of the sheet 22 instead of being defined between cuts 4 in the sheet 3. Apart from this difference, the comments made above about the construction and operation of the micromotor array 1 of Fig. 1 apply equally to the micromotor array 20 of Fig. 5.

Manufacture of the micromotor array 1 of Fig. 1 will now be described.

The micromotor array 1 is easily manufactured from a flat sheet 3 of material. The sheet 3 is cut to form the parallel cuts 4 defining each micromotor 2 and then shaped to angle the legs 5 away from the remainder of the sheet 3. To shape the micromotors 2, there must exist in the initially-formed sheet 3 a sufficient degree of flexibility to angle the legs 5 away from the remainder of the sheet. The electrodes 8 are easily applied by conventional techniques such as printing or electroplating.

Many ways to cut and shape the sheet 3 are envisaged, but the preferred method of manufacture is described below with reference to Figs 6 to 10.

(1) First, a flat sheet 3 of piezoelectric ceramic such as PZT is provided in the green state as shown in Fig. 6. As is known in the art, such a material in the green state is deformable and may be easily cut and shaped.

(2) The flat sheet 3 is cut to define the micromotors 4 by making the parallel cuts 4. The cutting is preferably performed as shown in Fig. 6 by passing the sheet 3 past a roller 30 with blades 31 in the pattern of the desired cuts 4.

(3) The cut sheet 3 is then pressed in a press to shape the micromotors 2 by deflecting the legs 5 away from the remainder of the sheet 3, so that the legs extend out at an angle away from the sheet 3. This may be performed in a press as illustrated in Fig. 7 consisting of (i) a former 32, for example of metal or ceramic, having protrusions 33 shaped to conform with the desired shape of the micromotors 2 and (ii) a relatively movable pressing element 34 having depressions (not shown) in a pattern corresponding with the protrusions 33 of the former 32 to conform with the desired shape of the micromotors 2.

As the entire sheet 3 may be cut in step (2) and pressed in step (3), the micromotor array is very easy to manufacture because all of the micromotors 2 within the array may be formed together, using the same, simple steps.

(4) The pressed sheet is then sintered to set the piezoelectric material of the sheet 3, in a manner which is entirely conventional for known structures of piezoelectric material. For example this may be performed as illustrated in Fig. 8 in two stages by firstly sintering the sheet 3 on the former 32 of the press to set the shape of the micromotors 2 in the sheet and secondly removing the sheet 3 from the former 32 and sintering the sheet 3 to burn out the binder and densify the material of the sheet.

(5) The next step is to plate both major surfaces of the sheet 3, across their entire area, with a respective layer of conductive electrode material as illustrated in Fig. 9. Any known electroplating or printing technique may be used and various possibilities are envisaged. One possibility is to print the electrode material with

pads. In this case the electrode material may be a silver frit in which case a further sintering for the silver frit is performed.

(6) Next the piezoelectric material of the sheet 3 is poled across the sheet by applying poling voltages across the conductive layers sufficient to pole the piezoelectric material therebetween in a direction across the sheet.

(7) Subsequently, the conductive layer is cut away to form the desired pattern of electrodes 8 and conductive strips 9 and 10, preferably using a laser.

(8) Optionally, the contact pads 8 may next be applied as shown in Fig. 10. Preferably, all the contact pads 7 for all the micromotors 2 of the micromotor array 1 are applied simultaneously using a carrier which holds each of the contact pads 7 in an array at positions corresponding to the positions of the bridging portion 6 of the micromotors 2. The contact pads 7 are provided with adhesive on their exposed surfaces and then the carrier is pressed against the micromotor array to affix the contact pads 7 to the bridging portion 6 of the respective micromotors 2. The advantage of applying the contact pads 7 using a carrier which has a rigid structure is that the outer surfaces of the contact pads 7 are aligned to be flat and level with a small tolerance. Any variation in the underlying structure of the micromotor is absorbed by displacement of the adhesive. Such alignment may alternatively be achieved after the contact pads 7 have been applied by pressing all the contact pads 7 with a flat sheet, or by lapping the upper surface of the micromotor array 1.

Numerous modifications to the preferred method described above are envisaged. Some such modifications are as follows.

Step (2) of cutting the sheet and step (3) of shaping the micromotors 2 may be performed simultaneously by pressing the sheet 3 in a press which has blades in a pattern to form the cuts 4 which define the micromotors 2.

Step (6) of poling the piezoelectric material of the sheet 3 may easily be performed after step (7) of cutting the conductive layers into the desired shape. Furthermore steps (5) and (7) which together form the pattern of electrodes 8 and conductive strips 9, 10 may be replaced by a single step of applying the conductive electrode material in the desired pattern one possibility is to apply a photoresist to

mask areas where the electrode material is not to be applied and then to plate the entire sheet 3, for example by electroless nickel plating. Another possibility to form the desired pattern is to print on a chemical which acts as a seed layer or modifies the surface selectively to make a subsequent plating process selective.

The pattern of electrodes 8 and conductive strips 9 and 10 may be formed (whether by steps (5) and (7) above or by the alternative of printing) at an earlier stage in the manufacture before step (4) of sintering. However, it is preferred that the electrodes 8 are formed after step (4) of sintering or else it is necessary to use materials for the electrodes 8 which are capable of withstanding the high temperatures during sintering, such as noble metals, which materials are expensive.

The micrometer array 20 of Figure 5 may be manufactured by the same process as described above for the micrometer array 1 of Figure 1 except that it is not necessary to cut the sheet.

Claims

1. A micromotor, comprising

a plurality of members of piezoelectric material, wherein the members are connected together at one end of each member from which the members extend to a support at an angle from each other so that the micromotor protrudes from the support,

each of the members having a pair of electrodes extending along the members on opposite sides of the members for applying an electric field across the material of the members, the material being poled parallel to the direction of the electric field.

2. A micromotor as claimed in claim 1, wherein the members are connected together through a bridging portion.

3. A micromotor as claimed in claim 2, wherein the bridging portion extends between the members at an angle to each of the members.

4. A micromotor as claimed in claim 2 or 3, wherein a pad for contacting an object to be moved is mounted to the bridging portion.

5. A micromotor as claimed in claim 4, wherein the pad is affixed to the bridging portion by adhesive.

6. A micromotor as claimed in any one of claims 2 to 5, wherein the micrometer is integrally formed by a portion of a sheet of piezoelectric matreial.

7. A micromotor as claimed in claim 6, wherein the portion of the sheet of piezoelectric material is defined by cuts in the sheet.

8. A micromotor according to claim 6, wherein the portion of the sheet of

piezoelectric material extends across the entire width of the sheet.

9. A micromotor as claimed in any one of claims 6 to 8, wherein the electrodes are provided on the major surfaces of the sheet.

10. A micromotor according to any one of claims 6 to 9, wherein the support is formed by the remainder of the sheet adjacent the portion forming the micromotor.

11. A micromotor according to any one of claims 6 to 10, wherein the support comprises a separate element coupled to the sheet.

12. A micromotor according to any one of the preceding claims, wherein the members are elongate.

13. A micromotor according to any one of the preceding claims, wherein the micromotor comprises two members.

14. A micromotor according to any one of the preceding claims, wherein the piezoelectric material is a piezoelectric ceramic.

15. A micromotor array comprising an array of micromotors each as claimed in any one of the preceding claims.

16. A micromotor array as claimed in claim 15, and integrally formed from a single sheet of piezoelectric material.

17. A micromotor array comprising a sheet of piezoelectric material, portions of which are shaped to form respective micromotors each comprising a plurality of members connected together at one end and each extending to the remainder of the sheet at an angle to the remainder of the sheet and at an angle to each other,

each of the members having a pair of electrodes extending along the members on opposite sides of the members for applying an electric field across the material of the members, the material being poled parallel to the direction of the electric field.

18. A micromotor according to any one of claim 14 or a micromotor array according toany one of claims 15 to 17, further comprising a control circuit arranged to apply a periodic control voltage across the pair of electrodes for each member of the or each micromotor with a predetermined phase relationship between the control voltages for each member.

19. A method of manufacture of at least one micromotor, comprising:

providing a sheet of piezoelectric ceramic in a green state;

defining at least one micromotor as a plurality of members connected together at one end of each member;

pressing the sheet to angle the member of the at least one micromotor away from the remainder of the sheet; and

sintering the sheet.

20. A method according to claim 19 wherein the at least one micromotor is defined by cutting the sheet.

21. A method according to claim 20, wherein said step of cutting the sheet comprises passing the sheet over a roller having blades defining a cutting pattern for the micromotors.

22. A method according to claim 19, wherein the at least one micromotor is defined across the entire width of the sheet.

23. A method according to any one of claims 19 to 22 , further comprising, at any stage in the manufacture, applying a pair of electrodes to each member

on the opposed major surfaces of the sheet and poling the sheet across the sheet.

24. A method according to claim 23, wherein said step of applying electrodes to each member comprises applying a conductive layer on the opposed major surfaces of the sheet across each member of the at least one micromotor and subsequently removing portion of the conductive layer to define separate electrodes for each member.

25. A method according to any one of claims 19 to 24, wherein

the at least one micromotor is defined with the plurality of members connected together by a bridging portion; and

in said step of pressing the sheet, the members are angled from the bridging portion.

26. A method according to claim 25, further comprising mounting a pad to the bridging portion.

27. A method according to claim 26, wherein the pad is affixed to the bridging portion by adhesive.

28. A micromotor constructed and arranged to operate substantially as hereinbefore described with reference to the accompanying drawings.

29. A micromotor array constructed and arranged to operate substantially as hereinbefore described with reference to the accompanying drawings.

30. A method of manufacture of at least one micromotor substantially as hereinbefore described with reference to the accompanying drawings.